Is operation time over the benchmark value a risk factor for worse short-term outcomes after laparoscopic liver resection?

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Abstract

Introduction: *Laparoscopic liver resection is a challenging surgical procedure that may require prolonged operation time, particularly during the learning curve. Operation time significantly decreases with increasing experience; however, prolonged operation time may significantly increase the risk of postoperative complications.*
Aim: *To assess whether prolonged operation time over the benchmark value influences short-term postoperative outcomes after laparoscopic liver resection.*
Material and methods: *A retrospective cohort study based on data from the National Polish Registry of Minimally Invasive Liver Surgery was performed. A total of 197 cases consisting of left lateral sectionectomy (LLS), left hemihepatectomy (LH), and right hemihepatectomy (RH) with established benchmark values for operation time were included. Data about potential confounders for prolonged operation time and worse short-term outcomes were exported.*
Results: *Most cases (129; 65.5%) were performed during the learning curve, while the largest rate was observed in LLS (57; 78.1%). Median operation time exceeded the benchmark value in LLS (Me = 210 min) and LH (Me = 350 min), while in RH the benchmark value was exceeded in 39 (44.3%) cases. Textbook outcomes were achieved in 138 (70.1%) cases. Univariate analysis (OR = 1.11; 95% CI: 0.61–2.06; p = 0.720) and multivariate analysis (OR = 1.16; 95% CI: 0.50–2.68; p = 0.734) did not reveal a significant impact of prolonged surgery on failing to achieve a textbook outcome.*
Conclusions: *Prolonging the time of laparoscopic liver resection does not significantly impair postoperative results. There is no reason related to the patients' safety to avoid prolonging the time of laparoscopic liver resection over the benchmark value.*

Key words: *laparoscopic liver resection, learning curve, operation time, short-term outcome, textbook outcome.*

Introduction

The laparoscopic approach for liver resection is an established method of treatment for patients with liver tumours. Consecutive prospective studies, including randomised controlled trials, have proven its feasibility and safety [1–3]. The increase in data

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has led to the publication of the most recent guidelines for laparoscopic liver surgery. These guidelines discuss indications and patient selection, major technical challenges of the procedure, and general assumptions regarding proper training and implementation in new centres [4].

According to multi-expert consensus, laparoscopic liver surgery should not be developed separately from an open liver surgery program. Proposed difficulty classifications of different type of procedures aim to facilitate maximising the safety of overcoming the learning curves and the efficiency in establishing new programs [5–7]. Despite optimal case selection, the learning curve for laparoscopic liver resection covers up to 40–60 cases per surgeon [8]. Successive acquirement of defined laparoscopic skills [9] results predominantly in reducing the operation time and intraoperative blood loss [10–12].

The reduction of operation time is a natural phenomenon observed during the training of any procedure. However, surgical data indicate an increasing risk of postoperative complications with prolonged operative duration [13]. Taking this into account, it is worth considering the implementation of a policy not to surpass a particular time during laparoscopic liver surgery, in order to avoid an increased risk of postoperative complications, even during the learning curve. Based on large-cohort data, there are established benchmark values for outcomes of the most repeatable types of liver resections, such as left lateral sectionectomy, left hemihepatectomy, and right hemihepatectomy [14, 15]. The most desirable surgical outcomes have been defined as textbook outcomes and are established also for laparoscopic liver resection [16].

Aim

The aim of this study is to assess whether prolonged operation time over the benchmark value influences short-term postoperative outcomes after laparoscopic liver resection.

Material and methods

A retrospective cohort study based on data from the National Polish Registry of Minimally Invasive Liver Surgery was performed (*registration number in clinicaltrials.gov;* NCT05516394) [7]. From 2010 to the end of 2022 there were 718 laparoscopic liver resections performed in 8 different departments in Poland. The median number of cases performed per department was 58, while 3 departments had experience of > 100 cases. Among all registered cases, 85.8% were performed by 10 different surgeons. Data from the registry covers the evolution of individual surgeons' learning curves, which were set for 60 procedures. Among all registered cases, only left lateral sectionectomy (LLS), left hemihepatectomy (LH), and right hemihepatectomy (RH) were selected based on the availability of benchmark values for operation time in the specified types of resections. In accordance with the study of Goh *et al.* the cut-off values were 209.5 min, 302 min, and 426 min, respectively [15]. The study cohort included 197 cases.

Data about potential confounders for prolonged operation time or worse short-term outcomes were exported from the registry and included the following: body mass index (BMI) [kg/m^2], previous abdominal surgeries, preoperative chemotherapy, stage of learning curve, type of tumour, maximum size of the tumour, number of tumours, liver steatosis, liver cirrhosis, application of Pringle's manoeuvre, number of surgeons, number of ports used, and technique of parenchymal transection.

For the assessment of short-term outcomes, data on intraoperative blood loss, intraoperative adverse events, postoperative complications, 30-day reoperation, readmission rates, and margin status were collected. Intraoperative adverse effects were defined according to the Oslo classification [17]. Postoperative complications were grouped according to the Clavien-Dindo classification [18]. Postoperative bile leak was assessed based on the International Study Group of Liver Surgery grading system [19]. For the complex assessment of surgical outcomes, Textbook Outcome was evaluated, which was defined as the absence of intraoperative adverse events of grade 2 or higher, postoperative bile leak of grade B or C, severe complications (Clavien-Dindo ≥ 3), postoperative reintervention within 30 days, readmission within 30 days of discharge, in-hospital mortality, and the presence of an R0 resection margin [16].

Statistical analysis

The descriptive statistics of the included cases based on resection range and cases exceeding the benchmark operation time value were recognised. Subsequently, univariate and multivariate analyses were designed to assess the risk factors of failing to achieve textbook outcomes. Data analysis was performed using SAS and Microsoft Excel 365. Continuous data were presented as median (Me) with interquartile range (IQR; Q1–Q3) and compared using the Mann-Whitney *U* test or Kruskal-Wallis test, as appropriate. Categorical data were presented as number (*n*) with percentage rates (%) and compared using Pearson χ^2 or Fisher exact test, as appropriate. Univariate and multivariate logistic regression analyses using the backward stepwise method to calculate the odds ratio (OR) were applied. Statistical significance was set for $p < 0.05$. The 95% confidence intervals (CI) were reported.

Results

The study cohort included 73 left lateral sectionectomies, 26 left hemihepatectomies, and 88 right hemihepatectomies (Table I). The median age for the whole study cohort was 63 (51.5–71) years, of whom 93 (47.2%) were female. Previous surgical treatment or neoadjuvant chemotherapy was observed more frequently among patients scheduled for left or right hemihepatectomies. Most cases (129; 65.5%) included in the study were performed during the learning curve, while the largest rate was observed in left lateral sectionectomies (57; 78.1%). A malignant tumour was an indication for surgery in most of the patients (172; 87.3%). Multiple lesions were observed most in patients scheduled for right hemihepatectomy (39; 44.3%). The median operation time exceeded the benchmark value in left lateral sectionectomies (Me = 210 min) and left hemihepatectomies (Me = 350 min), while in right hemihepatectomies a benchmark value of 426 min. was exceeded only in 39 (44.3%) cases.

Table I. Descriptive date of the study cohort

Variable	Total *N* = 197	LLS *n* = 73	LH *n* = 36	RH *n* = 88	*P*-value
Female	93 (47.2%)	38 (52.1%)	20 (55.6%)	35 (39.8%)	0.164
Age	63 (51.5–71)	60 (42.5–69)	69.5 (56.5–75)	64 (56–72)	0.011
ASA score	2 (2–3)	2 (2–3)	2 (2–3)	2 (2–3)	0.144
BMI [kg/m^2]	26.5 (23.7–30.1)	26.4 (23.2–30.8)	27.6 (24.4–30.4)	26.4 (24.1–29.6)	0.782
Previous abdominal surgery	92 (46.7%)	22 (30.1%)	19 (52.8%)	51 (58.0%)	0.001
Previous laparotomy	56 (28.4%)	14 (19.2%)	12 (33.3%)	30 (34.1%)	0.040
Preoperative chemotherapy	64 (32.5%)	11 (15.1%)	11 (30.6%)	42 (47.7%)	0.001
Performed during learning curve	129 (65.5%)	57 (78.1%)	19 (52.8%)	53 (60.2%)	0.011
Malignant tumour	172 (87.3%)	58 (79.5%)	33 (91.7%)	81 (92.0%)	0.050
Number of tumours	1 (1–2)	1 (1–1)	1 (1–2)	1 (1–2)	0.004
> 1	63 (32.0%)	15 (20.6%)	9 (25.0%)	39 (44.3%)	
Maximum tumour diameter [mm]	40 (28–60)	40 (30–53)	44 (31–69)	40 (25–67)	0.785
Liver steatosis > 30%	13 (6.6%)	2 (2.7%)	1 (2.8%)	10 (11.4%)	0.075
Liver cirrhosis	8 (4.1%)	5 (6.8%)	1 (2.8%)	2 (2.3%)	0.405
Pringle manoeuvre	89 (45.2%)	23 (31.5%)	14 (38.9%)	52 (59.1%)	0.002
Surgical team size	3 (2–4)	3 (2–3)	3 (2–3)	3 (3–4)	0.001
> 3 surgeons	54 (27.6%)	13 (18.1%)	7 (19.4%)	34 (38.6%)	
Number of ports	5 (5–6)	4 (4–5)	5 (5–6)	5 (5–6)	0.001
> 4 ports	152 (77.2%)	35 (48.05)	30 (83.3%)	87 (98.9%)	
Parenchyma transection with ultrasound selector	159 (80.7%)	58 (79.5%)	25 (69.4%)	76 (86.4%)	0.094
Operation time [min]	330 (210–420)	210 (170–307.5)	350 (217.5–420)	385 (315–487.5)	0.001
Prolonged operation time (exceeded benchmark value)	103 (52.3%)	45 (61.6%)	19 (52.8%)	39 (44.3%)	0.089

In comparison, in accordance with the operation time benchmark value (Table II) significantly more cases with prolonged operation time were performed during the learning curve (79.6%; $p < 0.001$). Operation time over the benchmark value was also observed more frequently in multiple lesions (42.7%; $p < 0.001$) and when the transection technique was based on the ultrasound selection device (86.4%; 0.046).

Intraoperative adverse events were observed in 37 (18.8%) of all cases and were comparable, regardless of whether the benchmark operation time value was exceeded or not (Table III). Severe postoperative complications, bile leak B or C, and 30-day reintervention or readmission rates were also similar between the 2 groups. Significantly more negative resection margins were observed in cases with prolonged operation time ($p = 0.011$); however, this did not result in a significant difference in textbook outcome rates between the groups ($p = 0.757$).

Textbook outcomes were achieved in 138 (70.1%) cases. During the univariate analysis prolonged operation time was not found to be associated with an increased risk of worse postoperative results (Table IV). However, a significant association was observed between worse short-term results and previous abdominal surgery (OR = 1.88; $p = 0.46$), the application of the Pringle manoeuvre (OR = 2.51; $p = 0.004$), or a larger surgical team (OR = 5.01; $p = 0.011$). Multivariate analysis was performed using the backward stepwise method until the step in which prolonged operation time would be eliminated in the next step (Table IV).

Table II. Comparison in accordance with the operation time benchmark value

Variable	Operation time within the benchmark value *n* = 94	Prolonged operation time *n* = 103	*P*-value
Operation time [min]	270 (175–350)	420 (295–510)	0.001
LLS	158 (131–179)	273 (240–349)	
LH	210 (150–285)	420 (363–480)	
RH	345 (285–375)	525 (480–600)	
Female	40 (42.6%)	53 (51.5%)	0.253
Age	63 (56–71)	64 (47–71)	0.559
ASA score	2 (2–3)	2 (2–3)	0.202
BMI [kg/m^2]	26.7 (24.8–29.5)	26.4 (23.4–30.9)	0.751
Previous abdominal surgery	44 (46.8%)	48 (46.6%)	0.999
Previous laparotomy	24 (25.5%)	32 (31.1%)	0.431
Preoperative chemotherapy	27 (28.7%)	37 (35.9%)	0.291
Performed during learning curve	47 (50.0%)	82 (79.6%)	0.001
Malignant tumour	79 (84.0%)	93 (90.3%)	0.205
Number of tumours	1 (1–1)	1 (1–2)	0.001
> 1	19 (20.2%)	44 (42.7%)	
Maximum tumour diameter [mm]	40 (25–55)	45 (28–69)	0.491
Liver steatosis > 30%	8 (8.5%)	5 (4.9%)	0.392
Liver cirrhosis	4 (4.3%)	4 (3.9%)	0.999
Pringle manoeuvre	39 (41.5%)	50 (48.5%)	0.390
Surgical team size	3 (3–4)	3 (2–4)	0.309
> 3 surgeons	28 (29.8%)	26 (25.2%)	
Number of ports	5 (5–5)	5 (5–6)	0.331
> 4 ports	74 (78.7%)	78 (75.7%)	
Parenchyma transection with ultrasound selector	70 (74.5%)	89 (86.4%)	0.046

Table III. Short-term outcomes in accordance with the operation time benchmark value

Variable	Operation time within the benchmark value *n* = 94	Prolonged operation time *n* = 103	*P*-value	Total *n* = 197
Intraoperative blood loss [ml]	300 (150–560)	300 (200–500)	0.739	300 (150–500)
IAE > 2	20 (21.3%)	17 (16.5%)	0.466	37 (18.8%)
CD ≥ 3	10 (10.6%)	13 (12.6%)	0.824	23 (11.7%)
Bile leak B or C	2 (2.1%)	9 (8.7%)	0.061	11 (5.6%)
30-day reintervention	5 (5.3%)	5 (4.9%)	0.999	10 (5.1%)
30-day readmission	3 (3.2%)	3 (2.9%)	0.999	6 (3.0%)
In-hospital mortality	3 (3.2%)	0 (0.0%)	0.106	3 (1.5%)
Margin R0	92 (97.9%)	91 (88.3%)	0.011	183 (92.9%)
Textbook outcome	67 (71.3%)	71 (68.9%)	0.757	138 (70.1%)

Table IV. Analysis of the risk factors of failing to achieve textbook outcomes

Variable	Textbook outcome *n* = 138	Failed textbook outcome *n* = 59	Univariate analysis OR (95% CI)	*P*-value < 0.05	Multivariate analysis OR (95% CI)	*P*-value
Female	77 (55.8%)	16 (27.1%)	0.30 (0.15–0.57)	0.001	0.29 013–0.69)	0.004
Age	64 (51–71)	63 (54–71)	1.00 (0.98–1.02)	0.978	0.99 (0.96–1.03)	0.674
ASA score 3	26 (51.0%)	45 (35.7%)	2.60 (0.79–8.51)	0.054	1.33 (0.24–7.37)	0.516
BMI [kg/m^2]	26.8 (23.8–30.1)	26.4 (23.6–28.6)	0.97 (0.92–1.04)	0.481	0.98 (0.90–0.07)	0.684
Previous abdominal surgery	58 (42.0%)	34 (57.6%)	1.88 (1.01–3.48)	0.046	1.77 (0.76–4.14)	0.189
Previous laparotomy	35 (25.4%)	21 (35.6%)	1.63 (0.84–3.14)	0.147		
Preoperative chemotherapy	40 (29.0%)	24 (40.7%)	1.68 (0.89–3.17)	0.110		
Performed during learning curve	87 (63.0%)	42 (71.2%)	0.69 (0.36–1.34)	0.272	0.60 (0.24–1.48)	0.267
Malignant tumour	117 (84.8%)	55 (93.2%)	2.47 (0.81–7.54)	0.113	1.91 (0.44–8.38)	0.839
Number of tumours	1 (1–2)	1 (1–2)	1.13 (0.58–2.17)	0.706	1.91 (0.28–1.88)	0.502
> 1	20 (33.9%)	43 (31.2%)				
Maximum tumour diameter [mm]	45 (30–63)	34 (20–53)	0.92 (0.82–1.04)	0.169	0.91 (0.78–1.06)	0.210
Liver steatosis > 30%	7 (5.1%)	6 (10.2%)	2.12 (0.68–6.60)	0.195	2.21 (0.54–9.10)	0.270
Liver cirrhosis	6 (4.3%)	2 (3.4%)	0.77 (0.15–3.94)	0.756	0.49 (0.08–3.09)	0.448
Pringle manoeuvre	53 (38.4%)	36 (61.0%)	2.51 (1.34–4.69)	0.004	1.87 (0.80–4.38)	0.147
Surgical team size	3 (2–3)	3 (3–4)	5.01 (1.92–3.06)	0.011	4.66 (1.32–16.4)	0.089
> 3 surgeons	22 (37.3%)	32 (23.4%)				
Number of ports	5 (4–6)	5 (5–6)	1.96 (0.87–4.39)	0.101	2.00 (0.62–6.40)	0.245
> 4 ports	50 (84.8)	102 (73.9)				
Parenchyma transection with ultrasound selector	112 (81.2%)	47 (79.7%)	0.90 (0.42–1.95)	0.807	0.62 (0.22–1.73)	0.360
Prolonged operation time (exceeded benchmark value)	71 (51.4%)	32 (54.2%)	1.11 (0.61–2.06)	0.720	1.16 (0.50–2.68)	0.734

Table V. Short-term outcomes in accordance with applying Pringle manoeuvre

Variable	Pringle manoeuvre n = 89	No Pringle manoeuvre n = 108	*P*-value
Intraoperative blood loss [ml]	400 (250–713)	250 (150–400)	0.001
IAE > 2	25 (28.1%)	12 (11.1%)	0.003
CD ≥ 3	10 (11.2%)	13 (12%)	0.999
Bile leak B or C	5 (5.6%)	6 (5.6%)	0.999
30-day reintervention	6 (6.7%)	4 (3.7%)	0.352
30-day readmission	3 (3.4%)	3 (2.8%)	0.999
In-hospital mortality	2 (2.2%)	1 (0.9%)	0.590
Margin R0	78 (87.6%)	105 (97.2%)	0.012
Textbook outcome	53 (59.6%)	85 (78.7%)	0.005

Post-hoc analysis was performed to evaluate the relationship between of application the Pringle manoeuvre and worse short-term postoperative results (Table V). Only in 53 (59.6%) cases where Pringle manoeuvre was applied was achievement of textbook outcome observed. A worse rate of textbook outcomes was associated with a significantly increased rate of intraoperative adverse events (p = 0.003) and a significantly decreased rate of R0 resection margin status (p = 0.012).

Discussion

After establishing the feasibility, safety, and efficacy of laparoscopic liver resection, the next step includes safe dissemination of this technique to the subsequent centres. Laparoscopic liver resection is a demanding procedure, which requires defined skills from advanced laparoscopic and open hepato-biliary surgery training [9]. Reasonable patient selection for laparoscopic liver resection is crucial, especially in the beginning of an individual's learning curve. A stepwise increase in case complexity, in accordance with established difficulty scores systems, may provide textbook outcomes on a satisfactory level during the learning curve [7]. The significantly increased operating time normally observed in the early phase of every learning curve brings into question its influence on postoperative results. How much should surgeons be concerned about the impact of prolonging the operation time over benchmark values in relation to postoperative results? Should trainees focus on agility training on simulators to maximise operative time reduction? Simultaneously, other potential risk factors of worse short-term postoperative results were assessed in this study.

Difficulty of liver resection may affect postoperative results [20]. The analysed cohort included 3 types of liver resection, representing all difficulty grades according to Kawaguchi *et al.* classification [6]. The LLS sub-cohort was significantly younger (p = 0.011), which could be related to less malignant indications (0.050) and a significant preference for scheduling surgery during the learning curve (p = 0.11). LH and RH were related to prior surgical or systemic treatment (p = 0.001). Major liver resections were less frequently performed before the completion of the learning curve. Prolonged operating time was observed significantly more often before completing 60 cases of laparoscopic liver resection for individual surgeons (p = 0.001). The duration of the operation over the benchmark value was more frequently seen in patients with multiple lesions (p = 0.001). Parenchyma transection with ultrasound selection was significantly more frequent in prolonged procedures; this dissection technique is known for being precise yet time consuming (p = 0.046).

A meta-analysis published by Cheng *et al.* [13], the largest cohort analysis so far, concluded that there is an association between increased risk of postoperative complications and surgeries with prolonged operative times. The analysis included a variety of specialities; however, the strongest association was observed with surgeries performed in general surgery. The causality of such a phenomenon may be explained in terms of the type of complication. The increased rate of surgical site infections could be attributed to prolonged microbial exposure, diminished efficacy of antimicrobial prophylaxis over time, or prolonged tissue retraction leading to tissue ischaemia and necrosis [21–23]. Such a pathophysiology is significantly reduced by a laparoscopic approach, for which small incisions for ports decrease the surgical site infection rates. Larger incisions are usually made only for specimen removal, making them far less exposed to infection [24–26]. Postoperative pulmonary complications are among the most common complications after liver surgery, and an increased rate may be observed, particularly after prolonged surgery [27]. Even though intraperitoneal insufflation may result in compromised lung ventilation, Fuks *et al.* presented an analysis in which they observed a significantly decreased pulmonary complication rate after laparoscopic major liver resections [28]. This may be justified by a less painful breathing limitation due to the lack of intensive rib retraction and a large incision in the epigastrium, which leads to faster postoperative pulmonary rehabilitation. Moreover, prolonging surgery simultaneously with increased intra-abdominal pressure may be linked to factors such as increased coagulation, blood stasis, and endothelial damage. These changes could result in a higher incidence of venous thromboembolism or acute kidney injury [29]. Additionally, the prolonged duration of procedures, leading to surgical team fatigue, may increase the likelihood of worse postoperative outcomes.

The performed study focuses on the impact of prolonged surgery on the ability to achieve textbook outcomes after laparoscopic liver resection. Based on the designed analysis, operation time over the benchmark value does not compromise the rate of textbook outcomes (p = 0.757). The only short-term result that significantly differs regarding the time of surgery is the rate of R0 resection (p = 0.011). However, it is also plausible that worse intraoperative outcomes can prolong the duration of surgery and thus contribute to the positive association between a positive margin and time exceeding the benchmark value. The regression model additionally showed no impact of prolonged surgery on achieving textbook outcomes. Contrary to expectations, applying the Pringle manoeuvre increased the risk over 2-fold in univariate analysis. To clarify such an unexpected association, a post-hoc analysis was performed (Table V). The reason for such an observation was that most surgeons performed the Pringle manoeuvre, especially during the learning curve, reactively to intraoperative adverse events rather than proactively to avoid increased blood loss. The approach for using the Pringle manoeuvre was verified by directly asking the surgeons who performed the operation.

The study's limitations include its retrospective character and the limited size of the cohort. However, even if studies designed for stronger evidence were to show such an impact, the current study suggests that, even if the potential association exists, it is likely to be very weak.

Conclusions

Prolonging time of laparoscopic liver resection does not significantly impair postoperative results. There is no patient safety-related reason to avoid prolonging the time of laparoscopic liver resection over the benchmark value, especially during the learning curve, when additional time is needed for safety and efficient training of a fellow.

Conflict of interest

The authors declare no conflict of interest.

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